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# Does the price of oil interact with clean energy prices in the stock market?☆

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ABSTRACT

In this paper, we analyze the relationships among oil prices, clean energy stock prices, and technology stock prices, endogenously controlling for structural changes in the market. To this end, we apply Markov-switching vector autoregressive models to the economic system consisting of oil prices, clean energy and technology stock prices, and interest rates. The results indicate that there was a structural change in late 2007, a period in which there was a significant increase in the price of oil. In contrast to the previous studies, we find a positive relationship between oil prices and clean energy prices after structural breaks. There also appears to be a similarity in terms of the market response to both clean energy stock prices and technology stock prices.



## 1. Introduction

Increases in oil price negatively affect economic activity and stock prices (Hamilton, 2003; Kilian, 2009). For example, most U.S. recessions are preceded by large oil shocks. There have been extensive studies analyzing the effects of oil price changes on the real economy, as well as their transmission mechanisms (e.g., Hamilton, 2003, 2009a; Kilian, 2008, 2009).[1] The previous literature suggests a positive association between rising oil prices and inflationary pressures on the economy (e.g., Fama, 1981; Darby, 1982; Cunado and Perez, 2005). Furthermore, many studies indicate a negative relationship between rising oil prices and stock prices (e.g., Hamilton, 1983; Huang and Masulis, 1996; Jones and Gautam, 1996; Sadorsky, 1999, 2001; Henriques and Sadorsky, 2008; Park and Ratti, 2008; Kilian and Park, 2009).

Although the aforementioned studies suggest a negative effect on stock prices from rising oil prices, there are several industries that benefit from higher oil prices. One such example might be the clean, or alternative, energy industry.[2] As oil prices increase, people are motivated to seek out alternative energy sources, albeit via imperfect substitutes, causing a surge in the price of alternative energy stocks. It is therefore worthwhile to examine the connection between clean energy stock prices and oil prices.

Once we consider the economic incentives related to the stock prices of green energy firms, there are a few applicable studies to examine. For example, Linn (2006) and Bushnell et al. (2009) examine changes in the stock prices of green energy firms as a function of external shocks, such as price changes in the carbon market and environmental regulations. To date, however, there exist very few studies examining the relationship between clean energy stock prices and oil prices. One such study is conducted by Henriques

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[1] It is also important to note that an increase in oil price has long-term effects on the economy. For example, a high growth rate in energy-saving technologies is observed when oil prices increase (e.g., Kumar and Managi, 2009).

[2] See Narayan and Sharma (2011) for evidence regarding the positive effect on the energy industry.

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and Sadorsky (2008), who analyze the relationship between clean energy stock prices and oil prices from January 3, 2001, through May 30, 2007 by using the vector autoregression (VAR) approach. They find that the stock prices of alternative energy companies are impacted by shocks to technology stock prices, but they also find that shocks to oil prices have little significant impact on the stock prices of alternative energy companies. Thus, the previous literature fails to provide evidence of a positive effect on clean energy stock prices from rising oil prices (see also Sadorsky, 2012). However, extending the data up to 2008 and applying the VAR in line with Henriques and Sadorsky (2008) and Kumar et al. (2012) show a positive relationship between oil prices and the stock prices of alternative energy companies. Therefore, how changes in the data affect the relationship is the remaining research question.

The main contribution of this paper is its further examination of the relationships among oil prices, clean energy stock prices, and technology stock prices. To this end, we extend Henriques and Sadorsky's (2008) study into the Markov-switching (MS) framework. The MS model provides a powerful tool for investigating an economic system with possible structural changes and asymmetric effects, which is arguably the case in our analysis, as discussed below. We note here none of the previous studies consider possible structural changes in order to understand the relationships among oil prices, clean energy stock prices, and technology stock prices.

Because oil prices have most likely had structural breaks in their time series data over the past 40 years, as pointed out by Hamilton (1983), it is not unreasonable to consider the possibility of structural breaks in the effects of oil prices on the economy. Moreover, there may be examples of significant changes in the interactions within the economic system that are causally related to oil prices. For instance, Kapetanios and Tzavalis (2010) analyze structural breaks in economic relationships, which are assumed to be driven by large economic shocks, such as oil shocks. They show that the first oil shock, at the end of 1973, had a large and long-term negative effect on economic activity, though the effect might not be large as was widely thought. If this is the case, the economic system may have been significantly altered as a result of the increase in oil prices during 2008. It is therefore crucial to use a model that can incorporate a possible structural change, such as the MS model employed by our study.

There are also a number of studies reporting the asymmetric effects of oil prices on economic activities (e.g., Hamilton, 1983, 1996; Mork, 1989; Jones and Leiby, 1996; Mork and Olsen, 1994). Although rising oil prices negatively affect economic activities, declining oil prices do not stimulate the economy. There are also several previous studies that report an asymmetric dependence in the stock market (Maheu and McCurdy, 2000; Ang and Bekaert, 2002; Okimoto, 2008). Because one of the main purposes of this paper is to examine the interactions among oil prices, clean energy stock prices, and technology stock prices, it is of great importance to consider the possibility of certain asymmetric effects among these three variables by using the MS model.

This study applies the Markov-switching vector autoregressive (MSVAR) models to the economic system consisting of oil prices, clean energy and technology stock prices, and interest rates. The results indicate that there is a structural change in late 2007, a period in which there was a significant increase in the price of oil. Although our results are entirely consistent with those of Henriques and Sadorsky (2008) before the structural break, we find that oil prices have positively impacted clean energy stock prices after the structural break, forming a striking contrast to the results of Henriques and Sadorsky (2008).

The paper is organized as follows: Section 2 describes the methodology of the MSVAR model. In Section 3, we present the data and discuss the empirical results. Concluding remarks are offered in Section 4.

## 2. Methodology

The main purpose of this paper is to examine the dynamic relationships among oil prices, technology stock prices, and clean energy stock prices, along with possible structural changes and asymmetric effects. To this end, we employ the MSVAR model. The VAR model can serve as a convenient tool for examining the interactions among variables, while the Markov-switching framework provides natural and tractable models for processes with switching regimes. By combining these two techniques, we can model regime switching interrelations with sufficient flexibility.

### 2.1. MSVAR model

The basic model used in this study is the recursive structural VAR model. To briefly illustrate the recursive structural VAR model, let $\mathbf{y}$ be an $n \times 1$ vector consisting of $n$ variables for examining dynamic relations. A reduced-form VAR model can be written as[3]

$$\mathbf{y}_t = \Phi_1 \mathbf{y}_{t-1} + \Phi_2 \mathbf{y}_{t-2} + \cdots + \Phi_p \mathbf{y}_{t-p} + \varepsilon_t \tag{1}$$

where $p$ is the lag length necessary to describe the dynamics of the system, $\Phi_j$ ($j = 1, \ldots, p$) are $n \times n$ coefficient matrices, and $\varepsilon_t$ is a disturbance term. We also assume that $\varepsilon_t$ is a Gaussian vector white noise with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Omega$.

One problem associated with the use of the VAR model (1) is the identification of structural shocks. To identify the structural shocks, we assume that the variables in the system have a recursive structure or are to be ordered according to their degrees of exogeneity, as proposed by Sims (1980). Under this recursive structural VAR assumption, the Cholesky decomposition can be used to identify the structural shocks. Once the structural shocks are identified, we can calculate the impulse response functions in order to analyze the interactions among the variables.

To capture the possible time variation in the interrelations between oil and stock markets, we introduce the MS framework into the recursive structural VAR model according to Sims and Zha (2006) and Inoue and Okimoto (2008). With this specification, the reduced-form VAR model (1) is expressed as

$$\mathbf{y}_t = \Phi_1(s_t)\mathbf{y}_{t-1} + \Phi_2(s_t)\mathbf{y}_{t-2} + \cdots + \Phi_p(s_t)\mathbf{y}_{t-p} + \varepsilon_t,$$

where $s_t$ is a latent variable taking the value of either 1 or 2. Moreover, $E(\varepsilon_t \varepsilon_t') = \Omega(s_t)$ is also assumed to be a function of $s_t$. In other words, this MSVAR model allows us to specify different VAR models for different regimes.

For the stochastic process of $s_t$, the MS model employs the Markov chain, as suggested by Hamilton (1989). The Markov chain is a simple model that describes the dynamics of a discrete random variable. The law of state evolution is governed by a transition probability matrix $\mathbf{P}$, where the $(i,j)$ element of $\mathbf{P}$ indicates $\Pr(s_t = i | s_{t-1} = j)$:

$$\mathbf{P} = \begin{pmatrix} p_{11} & 1 - p_{22} \\ 1 - p_{11} & p_{22} \end{pmatrix}$$

Although the model has a simple structure, it can characterize various types of state evolutions that depend on the elements of matrix $\mathbf{P}$. For example, the regime is very transitive if $p_{ii}$ is small, whereas it is highly persistent if $p_{ii}$ is close to 1 because the expected duration of each regime can be calculated by $1/(1 - p_{ii})$.

[3] The constant term is omitted for notational simplicity. However, all estimated models include a constant term.